

- A · B**, 403, 410
A × B, 416, 418, 422
A · B × C, 420
 $(A \times B) \times C$, 423, 425
 Absolute convergence, 381, 391
 Absolute minimum, 106, 505
 Absolute value, 3, 99, 212, 361, 365
 Acceleration, 19, 69, 105
 Acceleration vector, 449, 452, 462, 465, 469
 Addition formulas, 32, 33, 65, 291
 Addition of vectors, 398, 399
 Advanced placement, 161, 285
 AIDS, 53, 57
 Alcohol, 8
 Algorithm, 372, 598, 614
 Aliasing, 225
 Alternating series, 367, 382, 384
 Ampère's law, 596
 Analytic geometry, 121
 Angle between planes, 408
 Angle between vectors, 404
 Angular velocity, 339, 591
 Annuity, 248, 273, 309
 Ant, 259
 Anticommutative, 417
 Antiderivative, 182, 196
 Approximation, error, 93, 109, 111, 152, 221, 484
 linear, 92, 138, 255, 484, 489
 quadratic, 109-111, 255
 to e , 237, 241
 to integral, 220-227
 Arc length, 67, 320, 358, 449, 557
 Arcsine and arctangent, 172
 Arch, 277, 278
 Archimedes, 353, 371
 Area, 179-182, 201, 207, 215, 305
 between curves, 311
 definition, 201, 203, 216, 566
 of band, 326, 327
 of circle, 217
 of ellipse, 124, 220, 468, 565
 of parallelogram, 416, 418, 424, 533
 of region R , 564
 of ring, 530
 of slice, 523
 of sphere, 326, 360, 577
 of surface, 325, 574, 575
 of tilted square, 528
 of torus, 327
 of triangle, 351, 418, 424, 425
 of washer, 315
 of wedge, 357, 360
 polar, 357, 466, 529, 532
 surface of revolution, 326, 358
 under a curve, 184, 566
 under cycloid, 456
 under e^{-x^2} , 531
 under parabola, 183
 Arithmetic mean, 372, 404
 Arrows, 242, 250, 398
 Associative law, 434
 Astroid, 324, 456, 458
 Astronomy, 144, 354, 467
 Asymptote, 114, 115, 120, 125
 Attracting fixed point, 131
 Australia, 548
 Autoscaling, 43
 Average, 195, 210, 211, 329, 333
 distance 212, 535, 544, 548
 slope, 61
 value, 208, 531
 velocity, 44
 Axis, 124, 361, 590

 b^x , 230
 Back substitution, 442
 Backward, 207, 244
 Bagel, 316
 Balance of force, 286
 Balk, 29
 Ball, 23, 27, 28
 Balloon, 162
 Bar, 286
 Base of logarithm 228, 230, 239
 Base plane, 493, 574, 576
 Baseball, 29, 451, 454, 489, 513
 Basepoint, 387, 391, 511
 Basin of attraction, 130, 137, 487, 488, 489
 Basis, 600, 603
 Basketball, 22, 103, 327, 373
 Bell-shaped curve, 238, 330, 331, 335, 531
 Bending, 105, 107, 119
 Bernoulli(s), 151, 456
 Beta function, 309
 Binomial coefficients, 335, 387, 394
 Binomial formula, 51, 194, 270
 Binomial series, 393, 396
 Binormal vector, 461, 463
 Biochemistry, 265
 Biology, 57, 251, 261, 265
 Bipartite, 613
 Birdfeeder, 103
 Bisection, 146

 Black hole, 310
 Blackjack, 39
 Borderline, 306, 307, 379
 Boundary, 504, 508, 589, 596
 Box, 82, 86, 103, 104, 420, 438, 536
 Brachistochrone, 456
 Breadth first search, 612
 Buffon's needle, 213
 Burst of speed, 13, 285
 Bus, 552
 Business, 102, 247-249, 251, 269-274
 Butterfly, 356
 $B^2 - 4AC$, 127, 129, 509

 Cable, 278, 281
 Calculator, 40, 96, 132, 145, 225
 Calculus *T/L*, 39
 Cantor set, 142, 143, 382, 385
 Capital letters, 8, 16
 Car, 13, 20, 60, 450, 454, 459, 462, 546
 Cardioid, 353, 458
 Casio, 40, 132, 133
 Catalyst, 265
 Catenary, 278
 Cauchy, 83, 85, 309, 404
 Cauchy-Riemann, 570, 572
 Cavalieri, 319
 Celsius, 8, 165
 Census, 263
 Center, 118, 122, 124
 of curvature, 463
 of gravity, 531
 of mass, 336, 337
 point of calculus, 37
 Centered difference, 49, 108
 Centering, 118, 122, 127
 Central force, 464, 466, 469
 Central limit theorem, 333
 Centroid, 338, 340, 506, 534, 538
 Chain, 154, 169
 Chain rule, 156, 198, 215, 497-500
 Change of limits, 189, 206, 215
 of coordinates, 118, 532, 546
 of variable, 189, 190, 295
 Chaos, 140-144, 467, 487
 Chemistry, 407
 Circle, 123, 349, 351, 354, 450, 455
 Circulation, 568
 Class size, 211, 213
 Clock, 275, 405
 Closed curve, 560, 563, 566
 Closed interval, 89, 147

- Cobb-Douglas, 519
 Cobweb, 131, 136
 Coefficient matrix, 426
 Cofactor, 439
 Coffee, 252
 Cofunction, 175
 Coin tosses, 329, 370
 Column picture, 437, 441
 Column space, 600
 Compact disc, 417, 552, 591
 Company, 178, 183
 Comparison test, 307, 375
 Complementary angle, 32, 33
 Complete graph, 612
 Completing the square, 123, 298, 510
 Complex conjugate, 361
 Complex number, 360-362, 389, 601
 Composite function, 168
 Composition, 154
 Compound interest, 244, 245, 269, 271, 276
 Computer algebra system, 38
 Computing, 16, 36-43, 274
 (see Program)
 Concave, 69, 106, 111, 227, 510
 Concentration, 264, 265
 Conditional convergence, 382, 383
 Cone, 314, 327, 472, 476, 540, 574
 Conic section, 122, 127-129, 354
 Conjugate (complex) 361
 Connected, 566, 573, 615
 Conservation of energy, 344, 559
 Conservation of mass, 588
 Conservative, 551, 560, 564, 570, 594
 Constant,
 C, 181, 201, 205, 216, 561
 c (slope of b^x), 233, 236, 237
 factor, 72, 81, 197
 from y_0 , 260, 262, 604
 coefficients, 608
 Constraint, 514, 516
 Continuable function, 87, 90
 Continuity equation, 587, 589
 Continuous, 83, 86, 87, 148, 159, 204, 477, 480
 compounding, 269
 interest, 245, 251
 probability, 210, 328
 uniformly, 205
 Contour line, 472, 473, 474
 Convergence, 78, 374, 480
 absolute, 381, 391
 by comparison, 307, 375
 conditional, 382
 improper integrals, 306, 308
 interval, 391
 of series, 374, 381, 391
 of sum and product, 81
 squeeze theorem, 67, 83
 tests, 375-379
 to L , 79
 to zero, 78, 79
 Convex, 106, 474, 475
 Coordinates, change of, 532, 546
 cylindrical, 541
 polar, 348, 464, 469, 500, 532
 spherical, 543, 546, 577
 Coordinate-free, 399, 495
 Corner, 4, 46, 507, 518
 Corpse, 250
 Correction terms, 191, 193
 Cosecant, 29, 74, 257
 Cosh x , 277, 281, 386
 Cosine, 23, 26, 29, 70, 280, 365
 addition formulas, 32, 65, 291
 derivative of, 27, 68
 direction, 402
 law of, 34, 404, 545
 series, 386
 Cost, 506
 Cotangent, 29, 140, 146, 257
 Cover-up method, 301
 Cramer's rule, 428, 429, 434, 440
 Critical point, 99
 Cross derivative, 478, 480
 Cross product, 416, 418, 422, 573
 Cross section, 315, 317, 476
 Crosscut, 566, 592
 Cube, 219, 540
 Curl, 560, 586, 589, 591, 594
 Current, 552, 593, 607
 Curvature, 459, 462, 463
 Curve, integral along, 557
 length of, 321, 323
 parametric, 350, 446, 452
 polar, 352, 356
 simple smooth, 563
 slope of, 59, 62
 tangent to, 59, 449
 Curve ball, 451
 Cusp, 456, 458
 Cycle, 136, 141, 142, 489
 Cyclic, 418
 Cycloid, 455, 457, 458
 Cylinder, 104, 319, 541, 574
 Cylindrical coordinates, 541
 Czar's disease, 265
 Dam, 345, 347
 Damping, 605, 606
 de Moivre's formula, 362
 Decay, 243, 245, 249, 251, 271
 Decibels, 235
 Decimal, 85, 366
 Decreasing, 47, 96
 Definite integral, 185, 201, 225, 342
 Degrees, 8, 24, 29, 165, 473
 Del (∇), 492, 586
 Delta Airlines, 555
 Delta function, 14, 18, 116, 285, 288, 568, 570, 584, 598
 Delta, Δ , 44, 93, δ , 82, 90
 Deltoid, 458
 Demand, 46, 55, 272, 485
 Density, 336, 345, 526, 557
 Dependent variables, 47, 472, 501
 Deposit, 246, 271
 Depth first search, 612
 Derivative, 27, 44, 48, 476
 along path, 494
 directional, 490, 491
 mixed $\partial^2 f / \partial x \partial y$, 478, 480, 511
 of dot product, 463
 of inverse function, 166, 172, 175
 of b^x , 233, 237
 of e^x , 236, 268
 of $e^{u(x)}$, 239
 of $f(g(x))$, 156
 of $\ln x$, 237, 255
 of $\log_b y$, 234, 237
 of $\sin x$ and $\cos x$, 24, 26, 65
 of $\sin^{-1} y$, 172, 478, 480, 510
 of $\sinh x$ and $\cosh x$, 278
 of $\tan x$ and $\sec x$, 74
 of $\tan^{-1} y$, 173, 176
 of x^{-1} or t^{-1} , 46
 of x^2 or t^2 , 18
 of x^n , 52, 73, 76, 239, 390
 one-sided, 4, 477
 partial, 476
 rules for, 52, 71
 second, 69, 77, 171
 total, 499
 DERIVE, 39
 Descartes, 121
 Determinant, 420, 421, 422, 444, 445, 603
 in Cramer's Rule, 428, 440
 in cross product, 422, 590
 in inverse matrix, 430, 438, 601
 Jacobian, 532, 534, 546
 of product and sum, 434, 435
 Dice, 210, 334

- Difference equation**, 268, 271, 274, 609
Differences, 11, 178
Differentiable, 88, 89
Differential, 93, 102, 199, 483, 567
 equation, 53, 243, 286, 363, 597, 603
 logistic, 261, 266, 302
 partial, 479, 498, 571
 second order, 363, 604
 separable, 260
 series solution, 370, 390
 $y' = cy$, 243, 261
 $y' = cy + s$, 246, 250, 260
 $y'' = -y$, 69
Differentiation, 45, 476
 exponential (ED), 259
 implicit (ID), 160-164, 502
 logarithmic (LD), 256, 259
Diffusion equation, 479
Digital, 12
DiMaggio, 334
Dimension, 119, 143, 600
Dimensionless, 266, 267
Dimple, 353, 356
Dipole, 288
Direction, 398, 402, 490, 551
Direction cosines, 402
Directional derivative, 490, 491, 591
Directrix, 123, 355
Discontinuous, 4, 86, 87, 90
Discounting, 274
Discrete growth, 268
Discrete mathematics, 598, 611
Discrete sine, 12, 15
Distance, 1, 31, 449, 495, 506
 between planes, 415
 to line, 415
 to plane, 411, 412, 425
Divergence, of curl, 591
 of integral, 306, 308
 of series, 366, 375
 of vector field, 569, 570, 584, 586
 Theorem, 583, 595
Domain of function, 5, 41, 165
Dot product, 403, 404, 463
Double angle, 32, 290, 362
Double integral, 522, 528, 532
Double sum, 195
Doubling time, 57, 243, 245
Doughnut, 315, 358, 582
Driving a car, 1, 499, 604
Driving backward, 3
Driving time, 100, 116, 120
Drug, 251
 ds , 321, 323, 358, 449, 557
 dS , 573-577, 581
Duhamel, 247
Dummy variable, 188, 189
 e , 37, 236, 238, 254, 390
 e^x , 168, 228, 236, 242, 254, 268, 270, 386
 e^{iz} or $e^{i\theta}$, 280, 362, 388, 390
Earth, 356, 469
Earthquake, 235
Eccentricity, 354-356
ECG or EKG, 112, 401, 412, 415
Economics, 54, 57, 69, 474, 486, 489, 504, 519
Effective rate, 245, 273
Eigenvalue, 603
Einstein, 73, 96, 127, 163, 344, 347
Elastic, 102, 286, 342
Elasticity (economics), 54, 261
Electric field, 583, 593
Electrocardiogram, 112, 353, 401, 412
Elevator, 334
Elimination, 435, 441, 444
Ellipse, 122, 124, 127, 354, 466, 467
 area of, 124, 565
 in polar coordinates, 354, 356, 466
 parametric, 450, 453
 perimeter of, 124, 220
Ellipsoid, 539, 582
Endpoint, 89, 99, 186
Energy, 342, 344, 559
Engineering, 286, 343, 586, 606
Enzyme, 265
Epicycloid, 456, 458
Epsilon-delta, 79, 82, 90, 204, 480
Equal angle, 104
Equation,
 heat and wave, 479
 Laplace, 501, 503, 571, 586, 598
 logistic, 261, 262, 266, 302
 of a line, 58, 59, 409, 447
 of a plane, 408, 422
 of conic sections, 122-127, 354
 of normal line, 59, 481
 of tangent line, 59
 of tangent plane, 481, 483
Equator, 543
Equilibrium, 102, 485, 571, 586
Equipotential, 553
Error, 133, 153, 275, 392
 in approximation, 93, 110, 111, 152, 484
 in derivative, 109
 in integration, 221, 223
Error function, 331
Escalante, 285
Escape velocity, 309, 346
Escargot, 353
Euclid, 121
Euler, 236, 277, 609, 611
Euler's constant γ , 377, 381, 385
Euler's formula, 280, 362, 389
Euler's method, 274, 275, 609
Even, 75, 207, 213
Evolute, 463
Exact, 567, 572
Expected value, 209, 329, 369
Exponent, 228, 230
Exponential, 12, 167, 236, (see e^x)
 differentiation (ED), 259
 solution, 243, 363, 601
Extreme Value Theorem, 89, 99, 148
Factor, 301
Factorial, 38, 270, 307, 369
Faraday's law, 593, 596
Fast Fourier transform, 598
Feigenbaum, 142
Fence, 104, 513
Fenway Park, 458
Ferris Bueller, 3
Feynman, 98
Field line, 552, 553
Field, conservative, 560, 567, 570, 594
 gradient, 551, 556, 560, 564, 590, 594
 position, 550, 583
 spin, 550, 590
 vector, 549
Finance, 247, 251, 272
First order, 108, 221, 251, 275
Fixed point, 130, 272
Flight time, 454
Florida, 52, 475, 499
Flow, 555, 568, 582
Flow field, 552, 555, 569, 586
Flower, 352, 356
Flux, 555, 568, 570, 572, 579, 580, 585, 586
FM signal, 155
Focus, 123, 124, 354, 466
Football, 475
Force, 342, 345, 544
Force field, 555, 586

Index

- Forward-back, 3, 8, 25
 Four-dimensional, 219
 Fourier series, 116, 291, 294, 598
 Fourth order, 224
 Fractal, 88, 137, 139, 143, 487
 Fraction, 301, 367, 373
 Franklin, Ben, 245
 Frequency, 235, 608
 Fubini, 523
 Function, 4, 5
 continuable, 87, 90
 continuous, 86-89, 148, 159, 204, 477, 480
 delta, 14, 18, 116, 285, 568, 584, 598
 differentiable, 88, 89
 discontinuous, 4, 86, 87
 even and odd, 115, 207, 213
 gamma and beta, 309
 hyperbolic, 277, 298
 inverse, 164, 172, 196, 231, 279
 probability density, 211, 328
 rational, 300, 305
 step, 2, 14, 46, 86, 204, 285, 503
 Fundamental Theorem of Calculus, 19, 26, 149, 186, 213, 549, 556
 before limits, 11, 178, 195
 proof, 214, 216, 217
 Future value, 245, 273, 274

g and *G*, 467, 552, cover
 Gabriel's horn, 328
 Galileo, 19, 127, 339
 Galois, 160
 Gamma, Γ , 55, 309
 γ , 377, 381, 385
 Gas law, 502, 504
 Gauss, 189, 330, 372, 584-587
 Gauss points, 209, 224
 Generalized MVT, 151, 392
 Geometric, mean, 372, 404
 series, 16, 110, 181, 195, 271, 366, 368
 Gibbs phenomenon, 121
 Gradient, 492, 493, 495, 586
 Gradient field, 551, 556, 559, 560, 564, 590, 594
 Graph, 7, 36, 41, 112, 114, 472
 nodes and edges, 611
 of inverse, 167
 polar, 352
 semilog, 232, 235
 zoom, 41, 119
 Graphing calculator, 6, 39, 116
 Gravitation, 343, 466, 544, 548

 Gravitational constant, 467, 552, cover
 Gravity field, 548, 552, 554, 583
 Great circle, 555
 Greedy algorithm, 614
 Green's Theorem, 563-572, 587, 594
 Groove, 359
 Growth rate, 243, 261, 601
 Gyration, 341

 Half-life, 243, 251
 Half-plane, 508
 Hall's theorem, 613
 Halley, 146, 356, 371, 467, 470
 Hammer, 24
 Hanging cable, 278
 Harmonic motion, 25, 27, 69, 344
 Harmonic series, 80, 371, 375, 376, 380
 Heart, 112, 353, 400, 412, 415
 Heat equation, 479
 Helix, 450, 460, 461
 Hexagons, 34, cover
 Hole, 204, 315, 317, 375, 560, 566
 Hollow sphere, 545
 Homogeneous function, 504
 Homogeneous solution, 250, 602, 608
 Hooke's law, 102, 286, 342
 Hôpital (see l'Hôpital)
 Horizontal, asymptote, 114
 line test, 170
 slices, 218, 313
 Hose, 453, 457
HP-28S, 40, 225
 Hyperbola, 122, 125, 127, 354
 Hyperbolic functions, 277-280
 Hyperbolic substitution, 298
 Hyperboloid, 482, 483
 Hyperplane, 437, 538
 Hypocycloid, 324, 351, 456, 458, 572

i and *j*, 360, 401
 Identity, 31, 32, 140
 function, 155, 165
 matrix, 430, 534
 If and only if, 80, 85
 Imaginary number, 140, 253, 280, 360, 388
 Imaginary part, 363, 389
 Impedance, 610
 Implicit differentiation (ID), 160-164, 486, 502

 Improper integral, 297, 305-310
 Income, 178, 183
 Income tax, 9, 15
 Increasing function, 47, 96, 105, 153
 Increasing sequence, 204
 Indefinite integral, 185, 196, 342
 Independence of path, 559, 594
 Independent variable, 47, 472, 501
 Indeterminate, 149, 151, 236
 Indians, 245
 Indifference curve, 474
 Induction, 75, 190, 195
 Inequality, 208, 517, 520
 Schwarz, 195, 385, 404, 406
 Infarction, 113
 Infinite series, 366 (see Series)
 Infinity, 114, 151
 Inflection point, 107, 262, 511
 Initial condition, 260, 605
 Inner integral, 523
 Inner product, 403
 Inside function, 154, 157, 198
 Instability, 275
 Instantaneous, 17, 44
 Instructor, 305, 381
 Integral, 27, 180, 182
 along curve, 555, 557
 definition, 182, 203, 205, 522
 double, 522, 528, 532
 improper, 297, 305
 inner and outer, 523
 length, 321, 323
 line, 555, 557
 surface, 326, 581, 584
 test, 376, 377
 triple, 536, 541, 546
 using $\tan \frac{1}{2}x$, 292
 volume, 313, 316, 522, 536
 of $\cos^2 x$, 284, 289, 295, 312
 of $\cos^n x$ and $\sin^n x$, 290, 294
 of $\delta(x)$, 286
 of e^{cx} , 239
 of e^{-x^2} , 531, 535
 of $\ln x$, 283
 of $(\ln x)^{-1}$, 257
 of $\sec x$, 292
 of $\sec^3 x$, 291, 294, 300, 324
 of $\sin px \cos qx$, 291
 of $\sin^2 x$, 289
 of $\sin^m x \cos^n x$, 289
 of $\tan^m x \sec^n x$, 292
 of $\tan^{-1} x$, 284
 of $v(x)\delta(x)$, 286
 of $x \cos x$, 284

of xe^x , 285
 of x^{-1} , 234
 of $\sqrt{1+x^2}$, 294, 300, 324
 of $\sqrt{1-x^2}$, 295
 of $1/\sqrt{1-x^2}$, 295, 299, 300
Integrating factor, 247
Integration, by double-angle, 290
 by parts, 283-288, 587
 numerical, 220-227
 program, 226
Interest, 244, 245, 269, 271, 276
Intermediate Value Theorem, 89, 90, 209
Interval, 89, 147, 391
Inverse, 164, 196, 231, 237
 hyperbolic functions, 279, 281, 300
 matrix, 169, 429, 430, 435, 438, 534, 601
 of chain, 169
 secant, 174
 sine, 172
 square law, 544, 546
 tangent, 176
 trigonometric functions, 171-176
Invertible, 166, 170, 599
Involute, 458
Irrational, 591
Iteration, 130, 133, 155, 159, 272, 487, 490

Jacobian, 490, 532, 534, 546
Jump, 9, 14, 46, 86, 285

Kepler, 127, 464, 466, 467, 470
Kidney stone, 125
Kinetic energy, 344, 346, 559
Kinetics, 251, 264, 265
Kite, 104

Lagrange multiplier, 508, 514-520
Lamp, 327
Laplace equation, 501, 503, 571, 572, 586, 598
Law of averages, 333
Law of cooling, 249
Law of cosines, 34, 404, 545, 547
Law of mass action, 261, 264, 265, 267
Lawyer, 269, 455
Leading terms, 85, 191, 221
Leads in ECG, 413, 415
Least squares, 103, 431, 433, 600
Lebesgue, 205
Leibniz, 44, 48, 157, 177, 182, 431

Lemniscate, 355, 359, 360
Length, of cardioid, 358
 of curve, 321, 323
 of ellipse, 322, 325, 450
 of polar curve, 358
 of space curve, 325
 of spiral, 359
 of vector, 402, 403
Level curve, 472-474, 496
Level direction, 491, 492, 496
Lewis Carroll, 431
l'Hôpital's rule, 149, 153, 242, 248
Light ray, 63, 105, 123, 163
Limaçon, 353, 359
Limit, 19, 44, 78, 79, 84, 237, 480
 of a_n , 78
 of $f(x)$, 82, 85
 of $(1+h)^{1/h}$, 237
 of $(1+\frac{1}{n})^n$, 237, 241, 269, 276
 of $(1-\frac{1}{n})^n$, 241, 276
 of $(1+\frac{2}{n})^n$, 270, 275
 of $(\ln x)/x$, 258
 of $(\sin x)/x$, 65, 66, 70
 of $(1-\cos x)/x$, 65, 67
 of $\Delta f/\Delta t$, 44, 45
 of x^n/e^x , 242
Limit comparison test, 379, 381
Limit, one-sided, 83, 90
Limits of integration, 182, 186, 202, 524, 532
Line, 58, 447, 452
 equation of, 59, 61, 409, 447, 448
 integral, 549, 557
 normal, 59, 481, 489
 parallel or skew, 453
 polar form, 352
 secant, 61
 tangent, 58, 59, 92, 106, 137
Linear, 5-8, 71, 72, 197, 473, 597
 algebra, 425, 597, 599
 approximation, 92, 138, 152, 255, 484, 489
 combination, 71, 426, 600
 differential equations, 601, 603
 equations, 191, 426, 428, 436, 599
 programming, 516, 518, 597
ln x, 168, 237, 252
Loan, 248, 268, 273
Local, 21, 91, 146
 maximum, 98, 106, 505
Log-log, 232, 233, 235
Logarithm, 167, 228, 246, 252, 258
 approximation, 255, 395
 base b and e , 231, 237
 derivative of, 234, 237, 255
integral of, 283
 rules for, 229, 230, 235, 253
 series, 370, 373
Logarithmic differentiation (LD), 256, 259
Logistic equation, 261, 262, 266, 302, 304
Loop, 43, 474, 613
LORAN, 126
Los Angeles, 473, 555
Lottery, 52, 57, 248, 335
Lower rectangles, 187

Maclaurin series, 387
Magnetic field, 552, 593
Malthus, 244
Map, 292, 473, 474
MAPLE, 39, 196
Marginal, 54, 57, 102, 478
Mars, 353, 355, 469
Mass, 24, 28, 336, 526, 557
Mass action, 261, 264, 265, 267
Matching, 613, 615
Mathematica, 37, 39, 196, 290
Mathematical induction, 75, 190, 195
MATLAB, 38
Matrix, 420, 421, 427, 599
 multiplication, 429, 430, 438
Maximum, 89, 96, 505, 509
 local or absolute, 98
 test for 98, 106, 505, 509
Maxwell, 596
Mean Value Theorem, 18, 91, 97, 147, 151, 216, 217, 321, 480
 for integrals, 208, 214
Mean, 331, 332, 337, 373, 404
Median, 400, 406
Medicine, 112, 251, 400, 412, 415
Mercator, 292, 294
Mercury, 354
Michaelis-Menten (MM), 265, 267
Midpoint rule, 193, 204, 223, 527, 540
Minimum, 89, 96, 505, 508
 constrained, 514-520
 energy, 102
 test for, 98, 106, 505, 509
Mirror image, 167, 231
Mistake, 56, 213, 288, 359, 467
MIT, 99
MM equation, 265, 267
Mixed derivative, 478, 480, 511
Möbius strip, 479, 581, 582, 592
Modified Newton, 136

- Modulus, 361
 Moiré, 36
 Moment, 336, 338, 416, 526, 531
 Moment of inertia, 337, 338, 340, 528
 experiment, 339, 341, 548
 Monopoly, 56
 Monotonic, 166
 Mountain, 473-475
 Multiplication, 369, 388
 Multiplier, 134, 135, 514, 517, 520
 Multiply series, 370, 388, 396

 n choose j , 51
 Napoleon, 129
 Natural logarithm, 168, 237, 252
 Nearest point, 506
 Necessary, 80
 Needle, 213
 Nephroid, 356
 Network, 613
 New York Times, 268, 333
 Newton, 48, 148, 177, 265, 456, 470, 544, 547
 corpse and coffee, 250, 252
 law, 249, 339, 344, 464, 467, 606
 method, 120, 133-146, 153, 171, 487-490, 511
 program, 145
 Non-independent variables, 502
 Nonsingular, 427, 601
 Normal, distribution, 238, 330-332, 532, 535
 equations, 432, 433, 601
 line, 59, 481, 489
 to curve, 555, 568
 to plane, 407-411, 414, 443, 481
 to surface, 481, 483, 492, 573-581
 vector, 459, 461, 462, 573, 581
 Notation, 45, 157, 188, 431
 Nullspace, 599, 602

 $\frac{d}{dx}$, 45, 65, 149, 151, 480
 $O(\Delta x)$, 109
 Odd, 115, 207, 213
 Odd numbers, 178
 Odometer, 1, 3
 One-sided, 83, 86, 90
 Open, 89, 147
 Optimization, 516
 Order of accuracy, 221, 609
 Orientable, 581
 Orthogonal, 352, 533, 553
 (see Perpendicular)
 Oscillation, 12, 22, 24, 607

 Outer integral, 523
 Outside function, 154

 p -series, 378
 Pacemaker, 113, 412
 Paddlewheel, 591, 596
 Pappus, 341
 Parabola, 17, 59, 63, 122, 127, 141, 354, 454
 Paraboloid, 317, 477
 Paradox, 163, 310, 325, 360, 374, 501, 567
 Parallel axis theorem, 341
 Parallel line, 427, 448, 453
 Parallel plane, 408
 Parallelogram, 399, 406, 418, 425, 533
 Parameter, 322, 323, 326, 447, 557
 Parametric, circle, 23, 350, 449
 cycloid, 456
 ellipse and helix, 450
 equation, 350, 452
 projectile, 454
 surface, 574-582
 Partial, derivative, 471, 476
 differential equation, 479, 498, 571
 fractions, 240, 262, 300-305, 476, 481
 sum, 374, 384, 386
 Particular solution, 250, 602, 608
 Pascal's triangle, 51, 52, 387
 Path independence, 559, 594
 Percentage, 95
 Perimeter, 218, 220, 322, 325
 Period, 12, 468
 Periodic, 12, 30, 115, 143, 222, 291
 Permutation, 444
 Perpendicular (see Normal), 59, 163, 403, 448, 553, 600
 Petal, 352, 356, 359
 Phase angle, 34, 294
 π , 213, 236, 367, 371, 372
 Piecewise, 9, 22, 41, 167, 170, 563, 592
 Pilot, 348
 Pivot, 442, 444
 Pixel, 41
 Plane, 77, 329, 408, 422, 481, 483
 Planet, 464, 466
 Plato, 82
 Point source, 570
 Point-slope, 59, 409
 Poisson, 329, 332
 Polar, angle, 543

 coordinates, 348-351, 464-469, 500, 501, 532
 graph, 349-356
 rectangle, 529
 Pole, 86
 Police, 17
 Pool, 105, 347
 Population, 107, 187, 244, 262
 Position vector, 446, 465, 550, 583
 Potential, 342, 344, 414, 544, 552
 energy, 456, 559
 function, 551, 556
 Pound, 342, 468
 Power rule, 75, 157
 Power series, 366, 385-396
 Preconditioner, 133
 Present value, 245, 273, 274
 President, 10
 Pressure, 251, 345, 347, 478
 Prime number, 257, 381
 Principal value, 309
 Principle of virtual work, 287
 Prism, 536
 Probability density, 211, 328
 Product rule, 72, 77, 283, 587
 Professor, 71, 85, 171, 211, 305, 381
 Profit, 102, 104
 Program (TI - 81), 41
 autoscaling, 43
 cobweb iteration, 132, 133
 Newton's method, 145
 numerical integration, 226
 pieces, 42
 secant method, 145
 Projectile, 453-457
 Projection, 410, 411, 415, 425, 431, 432
 Proof without words, 192, 195
 Properties, of integrals, 206-209, 212
 of logarithm, 229, 253
 Pump liquid, 345
 Pure exponential, 363, 606
 Pyramid, 314, 346
 Pythagoras, 22, 31, 411, 419, 425

 Quadratic approximation, 109-111, 255
 Quadratic convergence, 135
 Quadratic formula, cover, 606
 Quark, 470
 Quotient rule, 74
 Race to zero, 87
 Radial field, 551, 553
 Radians, 12, 23, 24, 30

Radioactive, 244
Radius of convergence, 391, 393, 394
Radius of gyration, 341
Ramp, 13, 159, 288
Random, 210-212, 329-335
Range, 5, 43, 165, 454
Rate of change, 5, 48, 494
Ratio test, 378, 381, 391
Rational function, 85, 87, 300, 305
Ray, 63, 105, 123-126, 352
Real part, 363, 389
Rearrange, 84, 383
Reciprocal rule, 46, 73
Rectangles, 179-181, 191-193, 203-206, 523
Red light, 60
Reduction formula, 287, 290, 292, 300
Reflection, 63, 104, 123-126, 129
Related rates, 161-164
Relative change, 54, 95
Relative error, 193, 225
Relativity, 73, 96, 163, 164
Remainder, 347, 373, 392, 395
Removable, 86, 153
Reordering, 84, 383
Repeated factor, 303, 304
Repeated root, 605
Repeating decimal, 367, 373
Repelling fixed point, 131
Rescale, 34, 118, 300
Resonance, 604, 608
Reverse order, 525
Revolution, 314-320, 325-328, 542
Richter scale, 235
Riemann, 205, 377, 570
 integral, 203, 206
 sum, 202, 204
Rings, 217, 315
Rolle's Theorem, 147, 148, 153
Roller-coaster, 60, 494, 497
Root test, 378, 381, 391
Roots, 302, 360-365, 605
Rotation, 22, 119, 127, 416, 528, 550, 590
Rough point, 99, 505, 507
Row picture, 427, 436
Royal Mint, 125, 467
Rules, for derivatives, 71-76
 for integrals, 196, 198
 for limits, 81, 85
 numerical integration, 220-227, 527, 540
Runge-Kutta, 609, 611

Russian toast, 234
S-curve, 262, 263, 305
Saddle point, 477, 509, 582
SAT, 330-332
Scalar product, 403
Scale, 34, 118
Schwarz inequality, 195, 385, 404, 406, 519
Scientific computing, 274
Screw, 417
Seashell, 359, 360
Sec⁻¹y, 174
Secant, 29, 74, 174, 257
Secant line, 20, 60
Secant method, 144-146
Second, degree, 121, 127
 derivative, 64, 77, 105, 171, 500, 509
 difference, 15, 108, 195
 order, 108, 222, 484, 604
Self-similar, 143
Semilog, 232, 235
Sensitivity, 484, 515, 519
Separation of variables, 260, 603
Sequence, 78, 375
Series, 366, 374
 absolutely convergent, 381
 alternating, 382
 binomial, 394
 convergent, 374, 383, 392
 cosine and sine, 386
 exponential, 268, 378, 386
 geometric, 195, 366-374
 harmonic, 80, 375-377, 380
 Taylor, 386-390
Serret-Frenet, 463
Shadow, 24, 25, 162, 576, 596
Sharp point, 485
Shear field, 554, 557, 590, 591
Shell, 217, 316-320, 353, 545
Shift, 118, 158, 198
Shortest distance, 411, 415, 506
Shortest path, 611, 614, 615
Sigma, 188, 194
Sign matrix, 439
Simple, 86, 563, 565
Simply connected, 566, 567, 573
Simpson's Rule, 193, 223, 540, 611
Sine, 12, 23, 29, 70, 280, 365
 addition formulas, 32, 33, 65, 291
 derivative of, 24, 26, 65
 of n (on cover), 34
 series, 70, 387
 ($\sin h$)/h, 66, 70
sin⁻¹y, 172, 300
Singular, 440
Sinh x, 277, 281
Sink, 246, 568
Skew lines, 453
Slices, 312-316, 318, 327
Slide rule, 229
Sliding time, 456
Slope, 2, 20, 358, 494
Sloping asymptote, 115, 120
Smooth, 321, 563
Snail, 353
Snell's law, 105
Socrates, 79, 82
Solid of revolution, 314, 317, 542
Source, 246, 271, 568, 570, 584, 586
Space curve, 446, 589
Spanning tree, 613-615
Speed, 20, 324, 449
Speed of light, 163, 164
Speedometer, 1, 3
Sphere, 314, 482, 541, 543, 577
Sphere-with-hole, 317, 320
Spherical coordinates, 543, 546, 577
Spike (see Delta fcn.), 14, 285, 568
Spin field, 550, 551, 558, 561, 590
Spiral, 324, 353-356, 364, 464, 473
Spline, 288
Square, 218
 root, 96, 138-141, 578
 rule, 48, 50, 72
 wave, 116, 294
Squeeze, 67, 83, 85
Stable, 605, 609
Staircase, 15, 325, 343
Stand and Deliver, 285
Standard deviation, 238, 331, 332
State, 598, 611, 613
Stationary point, 98, 99, 505
Statistics, 432, 598
Steady state, 130, 249, 262, 264, 271, 272, 276
Steepest descent, 491, 511
Steiner problem, 506, 507, 512, 513
Step function, 2, 14, 46, 86, 204, 285, 503, 598
Stirling's formula, 242, 381
Stokes' Theorem, 563, 589-596
Streamline, 553, 554
Stretching, 286, 292, 532, 546
Strip, 220, 292, 311, 581
Subspace, 599
Substitution, 198-202, 240, 294-300
 hyperbolic, 298

Index

- successive, 135
 trigonometric, 296, 297
Sufficient, 80
Suitcase, 342, 343
Sum, 187-197, 374
 $1 + \dots + n$, 188-190
 $1^2 + \dots + n^2$, 190, 192, 195
 $1^3 + \dots + n^3$, 192, 195
 $1^p + \dots + n^p$, 193
 $1 + x + \dots + x^{n-1}$, 16, 85, 368, 372
Sums and differences, 11, 15, 177, 190, 220
Sun, 356, 464, 466, 585
Superattractive, 132
Supply = demand, 55, 272, 276, 485
Surface, 325, 397, 472, 573
 area, 325-328, 358-360, 544, 573-578
 integral, 578-582, 584, 592
Symbolic computing, 38, 290
Symmetry tests, 352

Table, areas and volumes, 317
 inverse trig. functions, 175
 of integrals, 196, T-0, cover
 of probabilities, 332
 $\mathbf{v}, \kappa, \mathbf{N}, \mathbf{a}$, 462
 $\tan^{-1} x$, 173, 176
Tangent, 29, 74, 257, 446
 arrows, 242, 250
 line, 58, 92, 106, 137
 plane, 481, 483
 vector, 459, 494
Tax, 9, 15
Taylor series, 109, 386-390, 511, 513
Taylor's formula, 288
Telescope, 178, 195, 380
Temperature, 8, 165, 249, 473, 478, 479, 499
Tennis, 373
Tensor, 495
Terminal velocity, 264, 281
Test D, 560, 593, 594
Test H, 570
Tetrahedron, 424, 525, 537, 540
Theorem (see Binomial, Mean Value, Fundamental Theorem)
Extreme Value, 89, 99, 148
Intermediate Value, 89, 90, 209

 Rolle's, 147, 148, 153
Squeeze, 67, 83, 85
Stokes', 592, 596
Thief, 64, 164
Thousand points, 34
TI-81, 40-43, 117 (see *Program*)
Tilted square, 527
Torque, 339, 341, 416, 469
Torsion, 463
Torus, 315, 327, 358, 582
Total derivative, 499
Total differential, 483
Train, 71, 457
Transform, 38, 118, 598
Transient, 249
Transpose, 424, 601
Trapezoidal rule, 222, 226, 275, 540
Tree, 613
Triangle, 29, 351, 400, 418, 424, 506
 inequality, 404, 406
Trigonometry, 22, 29-34
Triple chain, 158
Triple integral, 536, 541, 543, 546
Triple product, 420, 425
Trivial Pursuit, 341
Trochoid, 457
Turning, 550
Two-point form, 60

Uncle Sam, 268
Undetermined coefficients, 247, 608
Uniformly continuous, 205
Unit, 73, 345, cover
 circle, 278, 351, 363
 hyperbola, 278
 step function, 14, 159
 vector, 401, 402, 417, 464, 490, 495, 550
United Nations, 108, 262
United States, 125, 263, 268
Universities (map), 473
Uphill, 474, 492, 496
Upper limit, 188, 202, 215
Upper sum, 203

Variable, 18, 47, 101, 471
Variable endpoints, 215
Variance, 332, 335, 337, 532

Vector, 398, 446
 acceleration, 449, 452, 462, 465
 addition of, 398, 399
 angle between, 404
 binormal 461, 463
 components, 399
 field, 549, 550-555, 560
 normal (see *Normal vector*)
 position, 446, 465, 550, 583
 projection, 410, 411
 space, 599
 tangent, 449, 459
 unit, 401, 417, 449, 490, 550
 velocity, 446, 465, 551
Velocity, 1, 24, 147, 399, 446, 465, 551
Verhulst, 262
Vertex, 122, 125, 506
Vertical line test, 170
Viewing window, 38, 42
Visa, 277
Volume, 219, 420, 438, 478, 522
 by shells, 316, 318
 by slices, 312-316, 318
 in cylindrical coordinates, 541
 in spherical coordinates, 543, 546
 of a box, 420, 421, 438
 of a cone, 541
 of an ellipsoid, 539
 of a sphere, 217, 538, 544
 of a torus, 315

 w (weight-density), 345
Waiting time, 211, 332, 335
Washer, 314, 315, 317
Wave equation, 479, 503, 598
Wave, 281, 397
Weather map, 473
Wedge, 219, 295, 319, 357, 534
Whispering gallery, 125
Witch of Agnesi, 458
Work, 287, 342, 345, 555, 556, 558, 560, 594
Writing, 8, 39, 50, 71, 77, 85

X, 8
 $x^b = b^x$, 37, 258, 259
y-line, 264, 267, 271
Yes-no poll, 332, 333
Zeno, 188, 374
Zeta function, 377
Zoom, 6, 38, 42, 117, 120